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Two Segment 3D Kinematic Model of the Trunk in Spinal Cord Injury

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Trunk movement is a key factor in describing wheelchair propulsion in patients with spinal cord injury. Currently, there are two common methods for modeling the trunk segment using marker based motion capture technologies. The first method described by the International Society of Biomechanics (ISB) uses markers placed on bony landmarks of the spine and sternum. The second method is a more simplistic model using markers at each acromion and trochanter. Both of these methods describe the trunk as a single rigid body and therefore cannot delineate trunk motion at the mid thoracic region from total trunk motion. A more accurate model to describe trunk kinematics would provide additional information about trunk movement. The method described in this study uses the trochanter markers with the ISB marker set to create a two rigid body segment model to represent trunk motion referenced to the hip and trunk motion above the midpoint of the 8th thoracic vertebrae and the xyphoid process discretely. Creation of a 3D local coordinate system for each rigid body facilitates the use of Euler angle rotations to describe flexion/extension, lateral bending, and rotation at each segment. By comparing the acceleration at each segment, a model was created to describe a coordination profile between the upper and lower trunk. We anticipate the results of this study will provide new information related to trunk kinematics to be used for wheelchair design and fitting as well as the improvement of rehabilitation therapies related to wheelchair propulsion.

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Two Segment 3D Kinematic Model of the Trunk in Spinal Cord Injury

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INTRODUCTION

Previous studies of wheelchair propulsion in persons with a spinal cord injury have modeled the trunk as a single segment, many with one degree of freedom. The method described in this study added the trochanter markers to the ISB marker set to create a two segment model that represents motion of upper trunk segment (UTS) and the lower trunk segment (LTS) separately. The objective was to determine what new information on trunk movement could be obtained by using a two segment model.

DATA COLLECTION

Six subjects, who had given written informed consent, were asked to propel their own wheelchair on a custom built roller system at 2 mph. The rear wheels were replaced with a pair of SmartWheels – instrumented pushrims capable of recording 3D forces and moments. Pushrim kinetics were recorded at 240 Hz. Reflective markers were placed bilaterally on the lateral aspect of the acromion and the trochanter, in addition to those landmarks specified by the ISB recommendations. Kinematic data were collected at 60 Hz using a 7-camera Vicon motion capture system.

COORDINATE SYSTEM DEFINITIONS

UPPER TRUNK SEGMENT (UTS)

Origin: Midpoint of sternal notch (STN) and C7

Y: Vector connecting midpoint of the xyphoid process (XP) and T3* and midpoint of STN and C7 pointing superiorly

Z: Vector perpendicular to the plane formed by STN, C7 and the midpoint of XP and T3 pointing lateral to the right

X: Common line perpendicular to Y and Z axes pointing anteriorly

LOWER TRUNK SEGMENT (LTS)

Origin: Midpoint of XP and T3

Y: Vector connecting midpoint of XP and T3 and midpoint of the left and right trochanter pointing superiorly

Z: Vector perpendicular to the plane formed by XP, T3 and the midpoint of the trochanters pointing to the right

X: Common line perpendicular to Y and Z axes pointing anteriorly

*T3 was substituted for the ISB recommended T8 marker to accommodate participants with high seat backs.

DATA REDUCTION & ANALYSIS

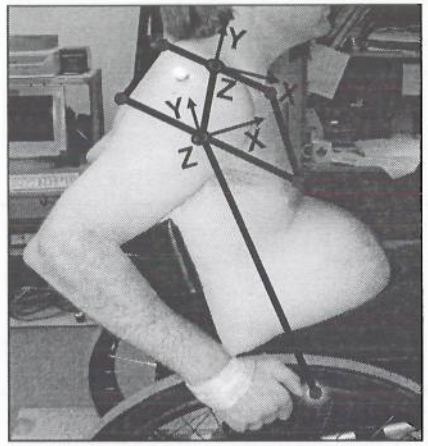
Ten propulsion cycles were used to establish the mean trunk movement pattern for each subject. Each cycle was defined as the period when a forward moment was applied to the SmartWheel. Data were normalized to 100% of the propulsion cycle.

3D angles of trunk movement were found using "zxy" order Euler rotations. Rotations included:

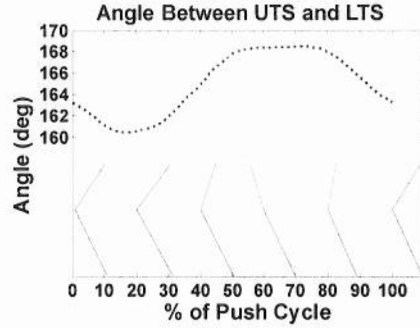
- The "upper trunk" to global (UTS Angle)
- The "lower trunk" to global (LTS Angle)
- The "upper trunk" to the "lower trunk" (Included Angle)

Only trunk movement in the sagittal plane was chosen for discussion.

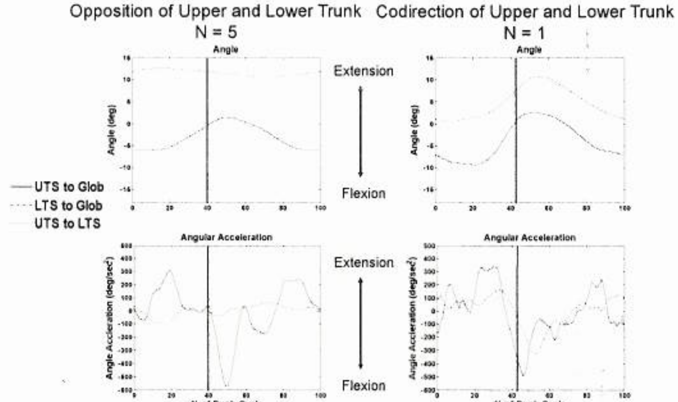
Angular velocities and accelerations were calculated for all angles, and a linear correlation coefficient (R^2) was found between the UTS Angle and the LTS Angle for push phase and recovery for all subjects. All data were analyzed using custom routines written in Matlab (Natick, MA).



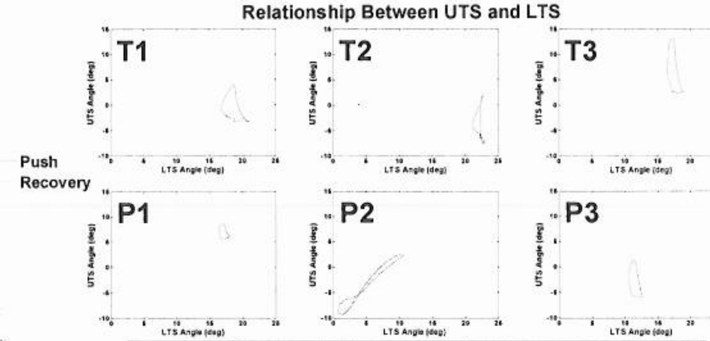
Angle Between UTS and LTS



Trunk Angle and Angular Acceleration



Relationship Between UTS and LTS



	Tetraplegia			Paraplegia		
Subject #	T1	T2	T3	P1	P2	P3
Functional Level	C5	C5	C5	T4	T7	T12
Push R²	-.73	-.45	-.74	-.79	.95	-.64
Recovery R²	.41	.73	.036	-.18	.99	-.018

RESULTS: TWO MOVEMENT PATTERNS

Opposing Movement of UTS and LTS

- Negative correlation coefficient
- Inverse relationship between upper and lower trunk angles
- Motion occurs primarily at mid thoracic level.

Co-directional Movement of UTS and LTS

- Positive correlation coefficient
- Direct relationship between upper and lower trunk angles.
- Motion of the trunk occurs at the level of the hip.

The angular acceleration of the trunk describes the temporal relationship between the segments. In the figure of codirectional movement, trunk motion is lead by the UTS and the LTS follows.

CONCLUSIONS

The use of a two segment trunk model enabled the identification of different movement patterns of the trunk. Calculation of angular acceleration of each segment produced a time dependent model of movement.

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